Keynote Speech

Agricultural Biotechnology Ten Years on: Lessons from the Past and Potential for the Future

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ABSTRACT

Since the first biotech crop was commercialized in 1996, today, theses crops are grown commercially by 8.25 million farmers on 200 million acres in 17 countries, and research and development is being conducted in another 45. The global commercial value of biotech crops grown in the 2003–'04 crop year is US$44 billion, 98% from five countries, US, Argentina, China, Canada and Brazil, growing one or more of biotech crops: soybeans, cotton, corn and canola. Although North America leads in research, more than half of the 63 countries engaged in biotech research, development and production are developing countries. The first generation of such crops focused largely on input agronomic traits, the next generation will focus more on value-added output traits. In the next decade some studies estimate the global value of biotech crops will increase nearly fivefold to $210 billion.

Key words: Biotechnology, Worldwide adoption, Agronomic traits, Output traits.

INTRODUCTION

Innovation is essential for sustaining and enhancing agricultural productivity. This involves new, science-based products and processes that contribute reliable methods for improving quality, productivity and environmental sustainability. Biotechnology has introduced a new dimension to such innovation, offering efficient and cost-effective means to produce a diverse array of novel, value-added products and tools. It has the potential to improve qualitative and quantitative aspects of food, feed and fiber production, reduce the dependency of agriculture on chemicals, diminish over-cultivation and erosion, and lower the cost of raw materials, all in an environmentally sustainable manner. Commercialization of the first generation of products of recombinant DNA technology was another facet in a long history of human intervention in nature for agricultural and food production purposes. As such, the same parameters of risk-based assessment should apply. Commercialization of products must be undertaken within a regulatory framework that ensures adequate protection of the consumer, the environment and alternate production systems while not stymieing innovation.

North America remains the epicenter of R&D on plant biotech, with the United States and Canada in the top five producing nations in terms of 2003-2004 commercial

biotech crop value: $2.0 billion in Canada and $27.5 billion in the United States primarily from soybeans, corn, cotton and canola. Thousands of field trials have been conducted in the two countries. From 1991 to 2004, the United States has conducted field trials, with traits being researched in 24 crops by 2004. Trials included research on fungal-resistant potatoes, peanuts, plums, bananas, rice, lettuce, salt-tolerant cucumbers, herbicide-tolerant peas, onions, tobacco and many others. Canada has produced, approved or field tested more field crops than any other country. The United States has approved in total 15 crops to date, including corn, cotton, canola, soybeans, chicory, cotton, flax, melon, papaya, potatoes, rice, squash, sugar beets, tobacco and tomatoes. In the next decade some studies estimate the global value of biotech crops will increase nearly fivefold to $210 billion.

Agricultural biotechnology has helped farmers around the world boost their productivity and grow crops in more ecologically healthy fields while allowing much more efficient use of resources. This technology allows reduced tillage, which cuts down on greenhouse gas emissions, water runoff, machinery use and soil erosion. A 2003 study of biotech crops by the National Center for Food and Agricultural Policy (NCFAP) found that eleven biotech crops planted in the United States produced an additional 5.3 billion pounds of food and fiber on the same acreage, improved farm income by $1.5 billion and reduced pesticide use by 46.6 million pounds. The NCFAP study found Roundup Ready soybeans offered several advantages to farmers, including easier weed management, less injury to crops, no restrictions on crop rotations, increase in no-till and cheaper costs. U.S. farmers using Roundup Ready soybeans saved an estimated $753 millions in 2001 due to lower herbicide costs. The broad spectrum of weeds controlled by glyphosate means that soybean growers no longer need to make as many multiple applications with combinations of herbicides. All together, the 40 case studies of 27 biotech crops showed that plant biotechnology can help Americans reap an additional 14 billion pounds of food and fiber, improve farm income by $2.5 billions and reduce pesticide use by 163 million pounds. In 2004, an additional NCFAP study demonstrated that US farmers who grew biotech crops garnered a 27 percent increase in net farm income (Sankula, 2004). Increasing yields on existing acreage reduces the pressure to convert forests and protected land into farmland. A more recent study by Brookes and Barfoot (2005) looked at the ten year impact of biotech crops since heir first large scale introduction in 1996. They showed that substantial net economic benefits at the farm level amounting to a cumulative total of $27 billions. In addition, the technology has reduced pesticide spraying by 172 million kg, reduced the environmental footprint of pesticide use by 14% and significantly reduced the release of greenhouse gas emissions from agriculture (Carbon sequestration). Biotech crops accounted for a reduction in 9.4 billion kg of carbon dioxide emissions in 2004 which is equivalent to removing five million cars from the roads.

The Food and Agriculture Organization (FAO) of the United Nations in a report issued in May 2004 found that biotechnology and genetic engineering of crops hold great promise for agriculture in developing countries. The report noted that more than

70 percent of the world's poor still live in rural areas and depend directly on agriculture for their survival. Of the eight point five million farmers who grew biotech crops in 2004, seven point six million (90%) of those were in developing countries. Agricultural research of all forms holds an important key to meeting their needs, the FAO said, and added that biotechnology can speed up conventional breeding programs and may offer solutions where conventional methods fail. That is good for growers, consumers, and anybody who cares about the environment. For example, in China, use of genetically engineered cotton eliminated the use of 156 million pounds of pesticides in 2001, an amount approximately equal to all of the pesticides used annually in California. A 2005 paper from the Royal Society suggests that intensive high-yield land-sparing farming is better for wildlife than "wildlife friendly" inefficient farming on greater acreage (Green, Royal Society 2005).

One of these modified crops, papaya is a major tropical fruit crop in the Asian region. However, production in many Asian countries is set back by the prevalence of the PRSV disease as well as post-harvest losses. The PRSV-resistant papaya, based on RNAi suppression of the coat protein expression, literally saved the $17M economy in Hawaii and is of significant importance in Taiwan and other SE Asian countries. Coat protein-based resistance is a demonstration of what is known as post-transcriptional gene silencing (PTGS). While initially it was considered a strange phenomenon limited to petunias and a few other plant species, it is now one of the hottest topics in molecular biology. RNA interference (RNAi) in animals and basal eukaryotes, quelling in fungi, and PTGS in plants are examples of a broad family of phenomena collectively called RNA silencing. In addition to protecting conventional papaya plants, by removing the virus reservoir the coat-protein (CP) protected papaya can help organic growers. There have been some claims that CP had sequences in common with a known allergen thus making them allergenic, however, this virus (with a complete in tact coat protein) has been reported on the islands since the 1940s and there have never been any reported cases ever of any allergenic reactions. Even if the CP has modified codons and was presented differently in the transgenic papaya, clinical tests have shown this makes no difference as ingested allergens are sequence specific at the amino acid level (stability) while inhaled allergens depend on protein conformation.

This system has now been applied to other species. A five year effort to combat plum pox vius disease through PTGS resistance paid off. In 1990, USDA/ Agricultural Research Service (ARS) scientists began their efforts with a papaya ringspot virus coat protein gene obtained from Dennis Gonsalves. This gene shows 70% homology to the plum pox gene and has been used to control other viruses similarly related to papaya ringspot. However, irrespective of the mechanism, it is important that resistance based on a single gene is managed well and alternate control mechanisms are introduced to reduce pressure on the development of viral resistance. Other approaches include expression of the RNA replicating enzymes of the virus, expression of satellite RNA, replicating RNA molecules that are molecular parasites of the virus or the use of protease inhibitors to interfere with processing of the viral proteins.

Scientific, civic, and religious opinion leaders from all over the world have expressed support for the value of this technology. Florence Wambugu of Kenya states that the great potential of biotechnology to increase agriculture in Africa lies in its 'packaged technology in the seed,' which ensures technology benefits without changing local cultural practices. For example over 120 million children worldwide are deficient in vitamin A. Potrykus (1999) group has engineered rice to accumulate provitamin A (b-carotene), Incorporation of this trait into rice cultivars and widespread distribution of this "packaged technology in the seed" could prevent 1 to 2 million deaths each year. She observes that in the past, many foreign donors funded high-input projects, which have not been sustainable because they have failed to address social and economic issues such as changes in cultural practice (Wambugu, 1999). In concurrence with this, Ismail Serageldin, Chairman of the CGIAR (Consultative Group on International Agricultural Research) noted that, a priori, biotechnology could contribute to food security by helping to promote sustainable agriculture centered on smallholder farmers in developing countries. For example 40% of the worlds irrigated land is no longer arable because of salinity Zhang and Blumwald (2000) have developed plants than can grow in soil that has 50 times the salt level of normal water. Similarly, a gene that produces citric acid in roots can protect plants from soils contaminated with aluminum (Lopez-Bucio J, 2000). Genes such as these can allow crops to be cultivated in hostile soils and temperatures increasing geographic range while reducing potential impact on fragile ecosystems.

The first generation of biotechnology crops focused largely on input agronomic traits, the next generation will focus more on value-added output traits. This will include identifying and isolating genes and metabolites that will make possible the enhancement of valuable traits, with some of the later compounds being produced in mass quantities for niche markets. Two of the more promising markets are nutraceuticals, or so-called "functional foods," and plants developed as bioreactors (production factories) for the commercial level production of valuable proteins and compounds, a field known as plant molecular farming (Newell- McGloughlin, 2005). Functional foods are defined as any modified food or food ingredient that may provide a health benefit beyond the traditional nutrients it contains. Scientific evidence is accumulating to support the role of phytochemicals and functional foods in the prevention and treatment of disease. Epidemiological research has shown a positive association between dietary intake of food components. Developing plants with improved quality traits involves overcoming a variety of technical challenges inherent to metabolic engineering programs. Both traditional plant breeding and biotechnology techniques are needed to produce plants carrying the desired quality traits. Continuing improvements in molecular and genomic technologies are contributing to the acceleration of product development. One estimate states that foods that are used for nutraceutical purposes made up 10 percent of the $503 billion total U.S. retail food market.

In addition to being a source of nutrition, plants have been a valuable wellspring of therapeutics for centuries. During the past

decade, however, intensive research has focused on expanding this source through rDNA biotechnology and essentially using plants and animals as living factories for the commercial production of vaccines, therapeutics and other valuable products such as industrial enzymes and biosynthetic feedstocks.

US Consumer attitudes also tend to be positive on the whole about agricultural biotechnology. A majority of them continue to be open to the benefits of food biotechnology, but less interested in the subject compared to other food issues, according to the latest survey conducted by the International Food Information Council (IFIC). It is notable that less than one-half of one percent of those who are avoiding something said they had avoided foods produced through biotechnology. In fact, in an International Food Information Council (IFIC) survey conducted in 2005 a clear majority of consumers (62 percent) expect food biotechnology to provide benefits for them and their families over the next five years, primarily in the form of better health/nutrition or improved food quality/taste/variety. They continue to indicate a willingness to purchase products of food biotechnology, particularly if biotechnology is used to reduce pesticides (64 percent), or improve taste and freshness (50 percent). Regarding the potential benefit of producing a more healthful oil, 41 percent state that this would have a positive impact, while 38 percent state that this would have no effect on their purchase intention. An overwhelming majority of consumers (76 percent) state that there is no information that they would like to see added to food labels, consistent with findings since 2001 when the question was first asked on the survey. Although support for the current U.S. Food and Drug Administration (FDA) policy on labeling food biotechnology has decreased over the years, more than half (55 percent) of consumers in 2005 say they support the policy, with more than a third expressing strong support. On an open-ended basis, only one percent name biotechnology as a labeling issue.

Although North America leads in research, more than half of the 63 countries engaged in biotech research, development and production are developing countries. China has emerged as a major center for biotech research. Its government has invested several hundred million dollars, ranking it second in the world in biotech research funding behind the United States.

But what of the context in which these crops are grown? Can all cropping systems co-exist in harmony? It is important to determine the relative importance of different crop production systems based on planted area, production and economic value to the region in question. The issue is what, if any, are the economic consequences of adventitious presence of material from one crop system within another based on the notion that farmers should be able to cultivate freely the crops of their choice using whichever production system works best in any given context (GM, conventional or organic). It is never a food or environmental safety issue but rather a production and marketing matter. According to Brookes and Barfoot (2004) biotech crops co-exist successfully with conventional and organic crops in North America (where, as noted, biotech crops account for the majority of acreage of important arable crops like soybeans, cotton and maize) and Spain. The market has developed practical,

proportionate and workable coexistence measures without new regulations or indeed any government intervention. Where isolated instances of adventitious presence of biotech material have been found in conventional or organic crops these have usually been caused by inadequate implementation of good coexistence practices (e.g., inefficient segregation of crops in storage and transport, nonuse of tested, certified seed). Under civil liability (i.e. tort damages) and for intellectual property infringement (except for the unauthorized StarLink), there have been no lawsuits brought by any parties for adventitious presence. Every case brought by a seed company for infringement has involved a claim that the farmer charged with infringement was an intentional infringer (i.e. adventitious presence was not the issue). And, to date, each of these cases was upheld by the courts. Indeed, all except one notable exception in North America conceded to this claim.

Within the EU, provision has been made for a *de minimis* threshold for unavoidable presence of GMOs but no actual threshold has been set. Therefore the default state of the 0.9% on labeling and traceability is the one enforced. In the US, organic products cannot be (legally) downgraded or the producer decertified by unintentional presence when all required measures and best practices are adhered to and no producer has been so impacted to date.

While biotech research and development in Europe slowed significantly following the European Union's 1998 de facto moratorium on approvals, which has since been lifted, Europe's stance on biotech crops can not prevent biotech adoption in the rest of the world and especially Asia is forging ahead. According to a study by Runge and Ryan (2004) as the EU becomes increasingly isolated, it will discourage its young scientists and technicians from pursuing European careers. If, on the other hand, the EU engages biotech in an orderly regulatory framework harmonized with the rest of the world, it will encourage a more rapid international diffusion of the technology. More nations will join the top tiers of commercial production, and emerging nations will continue to expand the sector.

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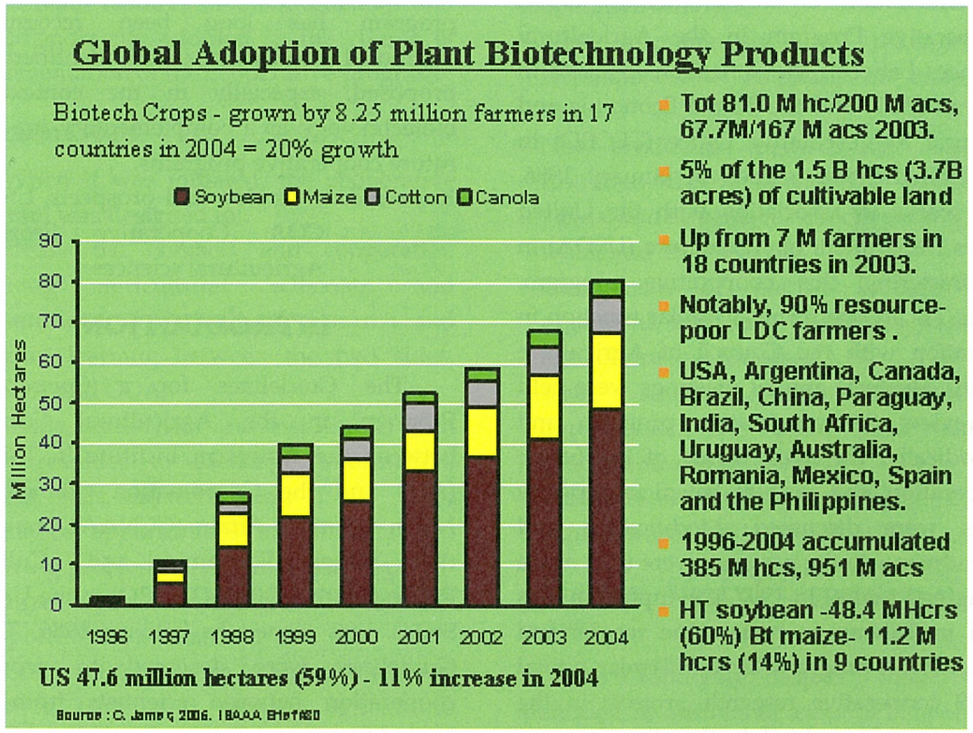
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